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RESEARCH REPORT

Preschool Teachers' Role in Establishing Joint Action During Children's Free Inquiry in STEM

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Abstract: *With science and digitalization emphasized further in the new Swedish preschool curriculum, there is a need to clarify teachers' role in educating children in and about these areas. In the present study, the Joint Action Theory of Didactics has been used to analyze the didactic game taking place between teachers and children in two preschools during inquiry-based STEM activities, with and without the use of robots during programming. The results highlight different coaching strategies used by the teachers and how these strategies promote the joint actions during children's STEM inquiry integrating programming and science. Interestingly, the joint action-strategies used by the teachers are similar and independent of whether the programming involves digital tools or not. Such strategies involve establishing a common ground of knowledge in the group and hands-on teaching. Both teachers start with teacher-scaffolded activities that develop into free inquiry and exploration through the children's own ideas, coached by the teachers on both individual and collaborative levels. The findings add to the discussion about how teachers can coach preschool children's learning and inquiry of programming and STEM – implications for preschool practice are discussed.*

Keywords: *Preschool, STEM, joint action theory of didactics, programming*

Introduction

During the years, the pedagogical task for Swedish preschool has gradually been reinforced and the national curriculum in 1998 introduced different goals to strive for and content areas to cover (Swedish National Agency for Education, 1998). One of these areas was science and in addition to defining this discipline from the, in preschool context, historical perspective of nature and outdoor experiences, the definition was during revisions of the curriculum broadened to include simple chemical processes and physical phenomena (Swedish National Agency for Education, 2010). Furthermore, from July 2019 a new preschool curriculum is implemented and this time with a strengthened focus on digitalization (Swedish National Agency for Education, 2018). This has resulted in questions being actualized about different didactic aspects such as what content, what methods, when to start and how to take children's perspectives into account, for both science and digital technology. As far as we know, there is no consensus among researchers or educators about how science, technology, engineering and mathematics (STEM) could be identified in a preschool perspective. The aim of this article is therefore to provide novel insight and knowledge of STEM activities integrating science and digitalization in a preschool setting.

Traditional school teaching has treated science, mathematics and technology as separate disciplines but an approach known as integrated STEM advocates for the introduction of these disciplines in an integrated modality since early age (Honey, Pearson & Schweingruber, 2014),

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which fits well with traditions in early-years teaching. The idea of STEM education is to view these disciplines as an entity, the teaching of which is integrated and coordinated as they are applied to problem-solving in the real world (Sanders, 2009). An effective STEM education has to consider children's interest and experience and promote rich and exciting experiences related to the four letters of/in the acronym (Toma & Greca, 2018). It also benefits from encompassing both domains of science discussed by Eshach (2006) in terms of content (concepts, theories, theoretical models) and investigations (hypotheses, problematizing, questions, experiments). In addition, robots are finding their way into classrooms and educational robotics is discussed as a transformational tool for learning computational thinking, coding, and engineering. Educational robotics has been described as an effective learning tool for project-based learning where STEM, coding, computer thinking, and engineering skills can be integrated (Eguchi & Uribe, 2017; Komis, Romero, & Misirli, 2016). In an extended overview of the field Bers (2018) discusses how coding engages children as producers and not merely consumers of technology, and that coding enables new ways of thinking, communicating and expressing of ideas. While the idea of integration when teaching subjects in school is rather new, interdisciplinary teaching is tradition in Swedish preschool. The different areas of the curriculum, such as language, aesthetics etc. are most often integrated and worked with in themes that last for an extended period. However, the handling of the content areas science, technology and mathematic stands out. A recent report by Swedish Schools Inspectorate (2018) describes how preschool teachers often experience an insecurity about work in the three fields, especially in technology, resulting in that work encompassing these goals in the curriculum is avoided in many preschools. We have previously reported on the insecurity experienced by preschool teachers when working with integration of science and digitalization (Authors, 2018a). This insecurity leads to many children being left out of the opportunity to develop further insight of the surrounding world here and now and interest for science and technology, which in turn may affect children's choice of studies later. It is therefore of utmost importance that knowledge is developed of how preschool teachers could implement teaching in these areas (Swedish Schools Inspectorate, 2018).

Joint Action Theory of Didactics

The analysis of this study was based on the Joint Action Theory in Didactics (JATD). Blumer (2004) argued that describing a social act equals describing a

> Joint activity, inside which the individual act is being formed as it is directed to fit into an ongoing patterning of the acts of others (pp. 32–33).

Sensevy et al. (2015) describe the teaching-learning process as a didactic game and a system, comprised of the teacher, the student, and the knowledge to be taught and learned. This system is inseparable and must be viewed as a whole, meaning that one cannot understand the teacher's behavior without at the same time understanding the student's behavior as well as the knowledge structure and function. The didactic game is thus a 'reciprocal game' between the teacher and student in which one player (the teacher) only wins if the other player (the student) wins, that is, learns. The teacher's task is to help the student in the game but in the end the student is the one who must make the 'winning moves', that is, conquer the new knowledge. The term knowledge in JATD is seen as a power of acting in a specific situation, referring to that when you know something, you become able to do something that you were unable to do before, in a specific situation (Sensevy, 2012).

The JATD puts forward three didactic concepts: joint attention (Bruner, 1977; Eilan et al., 2005), joint affordance (Gibson, 1979) and common ground (Clark, 1996). Sharing attention, that is, having a 'joint attention', on the same objects is crucial for a joint action. 'Joint affordance' refers to participants in the same joint action recognizing the same affordances in a given environment (Gibson, 1979) and the concept of 'common ground' (Clark, 1996) denotes the shared preconceptions and understanding of a common background in the situation, enabling communication between participants in joint actions (Sensevy et al., 2015). The didactic process may also be described through a contract-milieu dialectics, where the contract refers to the already established knowledge

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and the milieu to the new knowledge to be conquered through the didactic game. The contract and the milieu in a situation can be considered as complementary entities since new knowledge always refers to, and builds on, older knowledge and what is known from before (Sensevy et al., 2015).

Previous studies where the JATD have been used as an analytical tool have often focused older students and their teachers, working with technology (Svensson & Johansen, 2019), physics (Venturini & Amade-Escot, 2015) and biology and English (Gruson & Marlot, 2016). An exception to this is the article by Sensevy et al. (2015) that reports on JATD-analysis of two cases, one of which is from kindergarten. We see the JATD framework as suitable also for younger children where signs of e.g. attention could be interpreted from physical gestures, a complement if their verbal language is not as developed. The present study therefore extends earlier research with its aim to, via the JATD framework, analyze the didactic game taking place between teachers and children in two different preschools during their inquiry of programming in integrated STEM activities, with and without digital tools. More specifically, the research question guiding the analysis is:

- How are preschool teachers promoting the didactic game with children during inquiry in STEM, with and without digital tools?

Methods

The study originates from botSTEM, an ERASMUS+ KA201 project with partners in Spain, Sweden, Italy and Cyprus. One aim of botSTEM is to develop a research- and evidence-based toolkit, useful for teachers aiming to introduce integrated STEM approaches through collaborative inquiry teaching scaffolded by robotics for four-eight year old students (Greca Dufranc et al., 2020). An on-line toolkit with STEM practices has been developed and more information about the project can be found at botSTEM.eu. A part of the botSTEM project is to implement and evaluate activities from the toolkit and part of that is done by researchers and teachers in Sweden. Three researchers and ten preschools are involved in this process. Participating preschool teachers were part of different competence development courses in science, held by the authors, where they were introduced to the botSTEM project. Ten in-service teachers from the courses volunteered to join and in the present study, two of these preschool teachers, henceforth called Jannica and Caroline, were asked to try out and evaluate an optional botSTEM activity. During an introductory meeting attended by one of the researchers together with Jannica and Caroline, the toolkit was introduced and the methodology explained. Jannica chose the activity called 'Using the Blue-Bot as a link between different aspects of a natural science phenomenon'. The Blue-Bot® is popular in Swedish preschools for work with programming and digitalization. The transparent, beetle-like robot has a bluetooth function, but the Blue-Bot® can also be programmed physically through a set of buttons on its back. It can be programmed to take steps forward, backward, make 90 degree turns, and sequences can be repeated. In the chosen botSTEM activity, children's previous knowledge and experience of a science phenomenon could be coupled to programming through pictures of different aspects of the phenomenon placed on the floor. The children are supposed to program Blue-Bots® to go between two specific pictures. The teacher may e.g. ask the children to program the Blue-Bot® to find the correct animal food source picture among several pictures on the floor, or to go to the picture representing a tulip, among several flower pictures. In the present study, Jannica chose to develop the activity and make a new version of it, as explained further in the Results section. Caroline decided to try the botSTEM activity 'Children programming each other as Blue-Bots'. In this activity, three children work together with assigned roles as 'Blue-Bot®', 'programmer' and 'observer', respectively. On the floor are pictures of arrows in a winding path. For the 'Blue-Bot®' to follow the path, the 'programmer' programs him or her on the back in a manner resembling the buttons on the real Blue-Bot®. A press in the neck means 'forward', a press to the left of the back means 'turn left', a press on the lower part of the back means 'back', etc. Both Jannica and Caroline chose to develop their activities and make new versions of them, as explained further in the Results section.

Jannica, with 26 years of experience from work in preschool and with prior knowledge of the Blue-Bot®, chose four children, two girls and two boys aged five, to participate. Caroline has

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worked as a preschool teacher for 20 years but had no previous knowledge of the Blue-Bot® or programming, and in her activity, six children, four girls and two boys aged five, participated. Before the activities, the researcher asked for the children's permission to video record their activity. The activities lasted for 27 and 30 minutes respectively, and the whole activities were video recorded and analyzed. Throughout the activities, the teachers and children worked focused and the only exception from this was found in Caroline's activity, where the recording was paused for a short time when one of the children fell and started crying. When the activity started again, so did the recording. In a first step of analysis, the whole videos were transcribed, including description of gestures. In a second step, the transcripts were analyzed according to the JATD framework by both researchers for situations where establishment of joint attention, joint affordance or common ground could be inferred, either verbally or with bodily expressions, among the teachers and children. This was performed through double coding of the selected parts of the transcripts and final coding agreed upon by the researchers in relation to the JATD framework. In a third step, the selected situations were analyzed for patterns of didactic approaches. The didactic approaches represented teaching situations where the teacher successfully enabled establishment of a joint attention, joint affordance, or common ground, evident from the children's responses, either verbally or through actions and gestures. Five categories of didactic approaches were identified: Establishing a common ground, creating interest for the inquiry, hands-on teaching and learning, expanding the learning environment for the individual child and promoting collaborative inquiry through the children's own interest. Excerpts representing the five categories were chosen to exemplify the establishment of joint attention, joint affordance and common ground.

The research adheres to the ethical guidelines of the Swedish Research Council (2018). All participants and children's caregivers are informed and have agreed to voluntary and anonymous participation with a right to abandon participation. Written consent was collected from the parents to all involved children and the children themselves were always given the opportunity to withdraw and not continue to take part in the project. Pseudonyms are used in analysis and reports (see also, Farrell 2016, for a more in-depth discussion).

Results

In preschool 1, Jannica lets all children take part of her activities in small groups and she therefore repeats the activities on several occasions until all children have participated. The children that participated in this study were not especially chosen, but the only ones that had not yet tried out the activity. Jannica and the children start the activity on the floor with an activity involving one Blue-Bot® on a mat with a grid, the mat resembling a small town, see Figure 1. Some squares on the mat constitute streets and others shops. Since before, and therefore part of the common ground and the established contract in the group, the teacher and children have experienced programming the Blue-Bot® via the different buttons on its back. Also, they have for some months worked with the science content rocks and stones, hence the content is already experienced and part of the participants' common ground. In the activity that will follow (the didactic milieu), Jannica creates a didactic game that involves the children, one at a time, programming the Blue-Bot® to go from an optional start-square on the mat to an end-square, where another child has chosen to place the treasure stone. The child has to visualize how the Blue-Bot® needs to be programmed to reach the stone from the start-square and thereafter execute the programming on the robot. When all children have finalized, or tried, the programming, the second part of the activity starts with the children picking one Blue-Bot® each and creating an optional course for their Blue-Bot®. For this they choose freely between any available material in the room, such as KAPLA®-planks (Figure 1), blocks etc., for the Blue-Bot® to navigate in order to find stones that each child has placed somewhere on his or her course. The children are free to choose the arrangement themselves, also if they want to work alone or together with a peer. Two of the children chose to work alone, although, and as we will see, they later teamed up in a common activity, while two of the children worked in a dyad from the start. The children's inquiry took place on the floor with Jannica placing herself in the middle of them, so that she had an

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overview of the situation and could coach them when she found it suitable.

The common ground in preschool 2, and didactic contract, among Caroline and the children in her activity differs from the situation described above. While Jannica and 'her' children have previously worked with Blue-Bots®, the children in Caroline's activity have no previous experience of them. Instead, they have on a previous occasion discussed robots, what they are and where they can be found, and what the word 'instruction' means. This prior discussion was also the inclusion criteria for Charlotte when choosing children for the present activity. Thereafter, they programmed each other two and two by telling verbally what the other should do, for instance jump, dance, etc. In the present activity, Caroline sets up a didactic game and milieu around a group activity where the children for the first time walk a path as shown by arrows on papers placed on the floor. In the original botSTEM activity, only arrows were used as instructions, but on some of the papers, Caroline has added short instructions such as 'take two steps forward' and she helps the children by reading the instructions out loud to them (Figure 2). After having let each of the children try out the path, thereby enabling joint affordance among the children for what the arrows and instructions mean, Caroline expands the didactic milieu by opening up for free inquiry and for the children's own ideas of how to create paths of arrows and instructions.

Below follow excerpts from the activities, exemplifying the dynamics and aspects of the didactic game in progress between the teachers and the children. In focus are the different ways the teachers coach the children in a holding-back manner in creating a learning milieu through establishing a common ground and joint attention and through enabling joint affordances, during the inquiry.

Figure 1. Blue-Bots® in a KAPLA®-plank course on the mat.

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Figure 2. The 'arrow path' with instructions.

Didactic approach: Establishing a common ground

Both teachers start their activities by asking the children what they remember from previous activities, thus establishing the common ground and didactic contract in their respective learning situation. The children and Jannica are sitting on the floor around the mat and the teacher initiates the activity by asking the children what they remember about the Blue-Bot® and programming it:

Jannica	Do you remember what the different buttons meant? [She has picked up a Blue-Bot® and holds it in front of her so the children can see it.]
Mimmi	[Throwing herself forward to show with her finger on the buttons on the Blue-Bot®] Yes! There you press forward, there you press … [Hesitates for a second and Anton continues.]
Anton	Ehm, to the right!
Jannica	Schhh [To Anton, in order for one child talking at a time.]
Mimmi	… turn, there you press you should go backwards, there you press you should start, there you press when it should … do it again.
Jannica	When you should do it again, yes.
Mimmi	[Excited] Yes, and…
Jannica	… and then you can program once again. [Spins her hand in the air.]
Stella	I know what that one means. [Points to one of the buttons.]

Jannica only needs to start the activity with the question about what the children remember about the different buttons, and a joint attention is immediately established. All children pay attention to the discussion and when they, like Mimmi in the above example, recapitulate their previous common experience and hence their common ground, they show vividly with their body language and verbally how the Blue-Bot® can be programmed. However, it is not yet clear if also joint affordance is established for the children.

Caroline starts her activity by asking the children what they remember from the previous discussion about programming and robots:

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Caroline	And then we got into what a robot is. What is a robot?
Alice	Kind of a robotic lawn mower.
Elias	Yes, we should program the last time here there was a person you should say what it should do. Program and stuff.
Caroline	Yes, we programmed ourselves /…/ because you told me before what a robot can do. What could it do?
Alice	I know! It could cut grass.
Elias	Yes, I think one could build humans like robots on minecraft.
Caroline	Yes, and I think you were the one that said that you can explore planets and shoot them into space?
Elias	Mm
Caroline	Yes. And then you got the question if they can do these things themselves. Can a robot do it itself?
Alice	Yes, one could program.
Caroline	One could program them. And who is doing the programming?
Alice	Humans!
Elias	The humans who make them.

Through this initial discussion of robots and programming, and through Caroline's questions, she and the children establish the contract and common ground before moving into the new activity and learning milieu.

Didactic approach: Creating interest for the inquiry

After establishing what the group of children already knows and remember about programming the Blue-Bots®, Jannica introduces today's activity:

Jannica	[To Stella] Should you start? [Gives the Blue-Bot® to Stella]. I'll give you an assignment. I'll start by choosing a stone that you will go to. [Opens a plastic box and picks out one of the stones and says with a little exciting voice:] And then I'm gonna choose this one… [Inaudible]-stone. The treasure stone. [Shows the children the stone]
Stella	Wow…

In the situation, all children are following Jannica's framing of the didactic game with interest. She makes the activity exciting by giving Stella 'an assignment' and by using an exciting voice when she introduces the treasure stone. We interpret the word assignment and the exciting voice as didactic factors influencing the milieu and the joint attention in the situation. Another factor that promotes the joint attention for the children in the programming game, is Jannica's choice to let one child program and another child place the stone on a square. She thereby creates a situation where the children have more than one role, either as a programmer or as a 'stone placer' and in both roles the children's perspective is included. They get to choose themselves in what square to put the stone, and in what way to program the robot, respectively. Also, importantly, the Blue-Bot® itself functions as a motivation factor throughout the activity, helping to establish a joint attention. It is obvious from the children's reactions and excitement, physically and verbally, when it is introduced that they look forward to the activity and what will happen.

In Caroline's activity with the 'arrow path', she has included a question mark as one of the instructions. When a child reaches this, s/he get to choose for him- or herself what programming this should mean. This creates an interest and joy among the children, who e.g. jump, turn somersaults and cartwheels as response to the question mark. We see this inclusion of children's own ideas as a decisive step, and their joy of the chosen physical exercises, as a joint attention- and joint affordance-

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enabling factor in the activity.

In all, the robots, the 'assignment', Jannica's exciting voice, children's different roles on the Blue-Bot® mat, and the question mark allowing children to decide their own program steps on the arrow path, create an interest and a joint attention among the children participating in the milieus and didactic games.

Didactic approach: Hands-on teaching and learning

Striking from the data material is the amount of practical and hands-on clarification that goes on between the teachers and children, and between children, in the situations. Throughout the activity, Jannica in preschool 1 shows concretely with her hands what she refers to, thereby sustaining the joint attention and joint affordances in the coached open inquiry:

Jannica	Let's see if we can help each other out, here? [Estimates with her index finger on the mat the distance/squares the robot have to go.] One…
Stella	[Programs the robot]
Jannica	Two …
Stella	[Programs this step]
Jannica	Three …
Stella	[Programs]
Jannica	Do you need to turn? [Points first to the Fish-store that are placed one square to the left, and then to the square where Stella's robot will be on the street, to indicate the turn the robot needs to do.]
Jannica	Will you turn on that square? [Turns with the finger on the square]
Stella	[Programs the robot]

This kind of concrete presentation is constant during the activity. Both children and Jannica point and estimate with their hands during the discussions, enabling a mutual understanding of the situation and thereby sustaining the joint affordances they have the possibility to experience in the inquiry. Some children estimate with their hands how many squares the Blue-Bot® has to go while others only estimate with their eyes on the mat. The next example is from the second phase of the inquiry, where the children are free to choose arrangement around the optional course. Jannica shows Anton how he can build a course with KAPLA®-planks:

Jannica	If you take a kapla-plank, it's approximately the same size as the Blue-Bot® . [Illustrates by putting the kapla-plank and the Blue-Bot® next to each other on the floor.]
Jannica	Then you can build a path yourself if you want to. [Demonstrates by placing some kapla-planks in a row and on both sides of the robot so it stands in a small passage. Anton stands in front of the teacher and watches with interest.]
Jannica	Then you can put a treasure stone somewhere… [Mimmi reaches for the robot but the preschool teacher puts her hand over Mimmi's hand and the robot.]
Jannica	I'm just going to see if it works [she switches on the robot]. If it's as long as a kapla-plank. With a small space there [Adjusts the kapla-planks] I think it will walk one step per one kapla-plank. [Starts the robot and it walks exactly one step on the length of a kapla-plank.]
Jannica	[Looks at Anton] Did you see? So then you can calculate the course with kapla-planks.

After Caroline and the children in preschool 2 have walked and followed the instructions in the arrow path, the didactic game continues with the children re-building the path according to their

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own ideas. In the process, two girls walk the path they have created by walking from one paper to the next but ignoring the instructions on the way. Caroline therefore directs their attention to the instructions by joining in the walk, to physically show what happens if one follows the instructions that after the re-building ended up in an illogical order:

Caroline	Now I think I'm gonna try and walk.
Agnes	You start there. [Points to the paper with the arrow that the girls have chosen as starting point for their path.]
Caroline	You start here? [Stands on the start arrow and begins to read:]
Caroline	'Take one step back' [Takes one step back and ends up in another part of the path where Felicia already stands.]
Caroline	Then maybe I end up here? [The girls laugh.]
Felicia	That won't work!
Caroline	If I take one step back. Then I have to turn. [Turns around and faces the path.]
Caroline	Then it says 'Take three steps forward'
Felicia	Yes
Caroline	[Takes three steps forward but in doing so she walks the path in the wrong direction in relation to the arrows.] /…/ Do you see, Felicia and Agnes? What happened now? If I was here [Goes back to the start arrow], took one step back [Does so], then it says 'Take three steps forward'… [Takes the steps and ends up opposite Felicia who walks the path in the opposite direction. They are in each other's way.]
Felicia	[Laugs] But then I can't..! It won't work!

By showing hands-on and physically, the teachers and children make sure they understand each other's thoughts and intentions and we interpret this concrete teaching and learning as an important aspect of the milieu and didactic game.

Didactic approach: Expanding the learning environment for the individual child

In the didactic game, Jannica uses different strategies to support the individual children's free inquiry and the affordances the child may experience in the situation. One such strategy is to expand the children's use of scientific language. When a child mentions any of the different stones in the activity, Jannica answers by using the stones correct scientific name. An example of this can be seen when the teacher and two of the children are looking in the plastic box containing the stones:

Stella	These should be together all these [Refers to stones in her hand].
Jannica	Was that rose quartz then?
Stella	Mm. Rose quartz.
Linus	I'm gonna have this black stone.
Jannica	Mm, where did you find it? Was it black tonalite?

The teachers also use productive questions that expand the affordances in the children's inquiry, such as in the next example where Stella intends to program the robot to go into the Fish shop on the mat:

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Jannica	Should you try again? Reset again [Stella resets the robot]. What do you need to think about now? You need to go..?
Stella	[Crawls forward on the mat and shows with her index-finger which way she wants the robot to take, across the street and into the fish shop.]

The teachers also widen the children's possibility to learn by directing their attention towards new aspects and affordances of the inquiry they are conducting. During the free inquiry part of Jannica's activity in preschool 1, Mimmi and Stella is creating a competition for their Blue-Bots® to raise down an inclined plane (described below). Mimmi's suggestion is for the robots to raise upwards but Stella insists on downwards and the girls come to agree on that. Jannica notices the discussion and later, when Mimmi is using the inclined plane by herself, the teacher sees the opportunity to coach Mimmi back to her original thought (Figure. 3):

Mimmi	[Starts her robot. It goes downwards and stops at the end of the inclined plane.]
Jannica	Oh. But if you go upwards Mimmi, then what happens? Can it go upwards?
Stella	Yes! I know, 'cause..! [Starts to play claves with two kapla-planks.]
Mimmi	[Puts the Blue-Bot® so it will go up the plane, resets it and starts programming.]
Mimmi	… two, three, four. [The robot is started but immediately slips and ends up askew.
Mimmi	Eh! [Lifts the robot a little bit further up the plane and now it starts going straight up.]
Jannica	It was only in the beginning it needed help. [Soon after, the robot stops when it reaches the top of the plane. Mimmi applauds.]
Jannica	Good!
Mimmi	Wait … [Lifts the plane from the box its leaned against and leans it more steep against the box.]
Jannica	Are you going to try to have it even higher?
Mimmi	[Puts the Blue-Bot® against the now very steep plane, holds it in her hand and tries out the inclination. The plane falls over.]
Jannica	Do you think it can go upwards this slope?
Mimmi	Yes
	[Puts the Blue-Bot® at the end of the plane, facing upwards.]
Jannica	Maybe it needs help in the beginning.
Mimmi	[Programs the Blue-Bot® about five centimetre up the plane and Stella follows with interest.]
Mimmi	Reset! One, two, three, four, five.
Jannica	And go!
Mimmi	[When Mimmi is ready she lets go of the Blue-Bot® that slowly starts to slide backwards on the steep plane. She holds with both her hands around the robot while it slides, ready to capture it if needed. She takes the robot and lifts it higher up the plane to see if it goes better there but it slides backwards also from here. Mimmi takes it and laughs fondly.]
Jannica	[Laughs] Was it that steep? Okey. Can we find something in between here then, with the boxes? He managed that one [Holds with one hand on the lower box]. And that one was too steep [Holds on the higher box]. What could we have that's in between, Mimmi?

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Figure 3. Mimmi programs her Blue-Bot® to go down an inclined plane.

The above excerpt illustrates how the teacher pays attention to the affordances Mimmi sees in her inquiry when she is curious about the robot going upwards and on different inclinations. Jannica detects Mimmi's intentions and aids in her problem solving by offering another box and by asking questions such as "Can we find something in between here then, for the boxes ?", referring to finding a box that will give the plane an inclination that is "not too steep but not too easy either". Thereby, she enables a situation of joint attention and joint affordances between herself and Mimmi around the robot and the inclined plane.

A little bit later Mimmi has stopped exploring the inclined plane and instead starts to program the robot to enter a farmhouse standing on the floor. She estimates how many steps the robot needs to go to enter through the opening in the house and programs the robot accordingly. She tries to get the teacher's attention in doing so but fails since Jannica is involved in talking to another child. After the conversation the teacher turns to Mimmi and watches her program the robot, which then enters the farmhouse and stops as planned. Jannica missed how Mimmi estimated the distance with her hand and sees the opportunity to challenge Mimmi from a meta-perspective, by asking Mimmi to explain her reasoning behind the programming:

Jannica	[Puts her hand om Mimmi's arm.] But Mimmi, how could you know how many steps it should go? There are no tracks… [Shows with her finger on the farmhouse floor where the Blue-Bot® just went.]
Mimmi	'Cause I counted.
Jannica	How did you count?
Mimmi	One, two, three. [Shows with her hand on the farmhouse floor.]
Jannica	But there are no marks that one can follow like in the map over there? [Points to the mat with the grid] Did you just think [Points to her head] that it was approximately this long when it went, or?
Mimmi	[Nods]
Jannica	You could think that in your head?
Stella	[Loudly to the teacher] Do you know that..!
Jannica	You'll have to wait Stella, I'm talking to Mimmi now. How could you know how many steps it should take?

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Mimmi	‘Cause it… [Shows the teacher and speaks inaudible.]
Jannica	You counted and thought in the head?
Mimmi	[Nods]
Jannica	Smart!

The teacher’s approach to ask the children about their intentions and thoughts during their free inquiry so that she can follow them creates means for joint attention and joint affordances between the teacher and the children. In the next example, Anton has put his robot on the lid on a box and built a tower of small wooden blocks below the box. He programs the Blue-Bot® to go off the edge on the box, falling towards the tower:

Jannica	[To Anton] What’s happening here, what is it that you do?
Mimmi	[Sees that the robot is about to go off the box and puts her hands around it to capture it. With her arm-movement she accidently tips over some of the blocks of the tower.]
Anton	No! [The Blue-Bot® goes off the edge and falls to the floor, through the tower that falls down.]
Jannica	Wow. But I’m not sure the robot can withstand it so it was quite smart of Mimmi to try and catch it, actually. I don’t know how much they can withstand. But what did you think when you did it?
Anton	That it should go downwards.
Jannica	And tip the tower over?
Anton	No, I mean that it went like this and then brsch… [Shows on the edge of the box how he meant for the Blue-Bot® to go down the tower.]
Jannica	Aha, that it should come down on the tower and then come down?
Anton	Yes
Jannica	Aha, like a stair, or?
Anton	Mm
Jannica	How could it do that [Inaudible]. We need to ponder over that one. Maybe we can use larger blocks? Try them? [Takes out a box with soft, large blocks.]

What at first seems like a somewhat careless handling of the Blue-Bot® and a ruining of a tower is actually part of a more serious inquiry. It appears that what the teacher interprets as a tower of blocks is for Anton some sort of ‘staircase’ to help the Blue-Bot® downwards towards the floor. The intention is not for the tower to fall. Jannica’s choice to ask Anton “But what did you think when you did it?” allows for her and Anton to stay on the same track in the inquiry. By clarifying Anton’s intention, she creates means for joint affordance between the two of them in experimenting how they could build a sturdier staircase for the Blue-Bot® to go down by. Anton and the teacher continue the activity by building the stairs with larger blocks, discussing and trying the feasibility of the arrangement.

Didactic approach: Promoting a collaborative inquiry through the children’s own ideas

In the data material, several examples of the children’s agency and ownership of their inquiry are visible. The following excerpt exemplifies the joint affordances Anton and Linus experience during the second part of Jannica’s inquiry activity, where the children arrange their own courses for the Blue-Bots®:

	[Anton and Linus sit by the mat with a box of kapla-planks between them. Linus holds a Blue-Bot® and watches while Anton starts to build with kapla-planks along the grid/street so that two kapla-planks flank one square and a path is created between the kapla-planks.]
Jannica	Do you want kapla-planks in the [Inaudible]-course? [To Anton who does not answer] Or do you want to build it outside on the floor?
Linus	[To Anton] I’m actually gonna drive this way.

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	[Puts the Blue-Bot® on the mat so that the robot will cross the path Anton is building on.]
Anton	Aha! Then we can do like this.
	[Puts a kapla-plank so that the path folds in 90 degrees in the direction Linus intended.]
Linus	Okey, then I can drive and break your building here [You can tell from his face that he is joking and both boys laugh]. Shall we both make the path?
Anton	Yes
Linus	Shall we make a path over all of this, over the whole road?!
Anton	Yes we can! If anyone wants to drive there, then there's just a path!

Soon after they are inspired by the preschool teacher who says to Mimmi:

Jannica	Are you gonna try to build a bridge, Mimmi? [Mimmi has started to build a bridge with kapla-planks]
Anton	A bridge yes! Don't you think we should do that Linus?
Linus	Yeees! A bridge here.

In the excerpt, joint affordances between the children are detected when Anton and Linus choose to build their course, or path, together. Anton swiftly changes his course of KAPLA®-planks to meet Linus' intentions for the direction of his robot. A balance in their collaboration is seen throughout their activity. They are both active and attentive to the other's suggestion, they negotiate and confirm each other's ideas, factors we interpret to strengthen their joint attention and affordances in the inquiry and in the didactic milieu. A bit further into the activity Anton comes up with a plan for their two robots to bump into each other (Figure 1):

Anton	And we can try to crash too!
Linus	What?
Anton	We can try to crash.
Linus	Yes!
Anton	Jannica! Do you know what I and Linus will do?
Jannica	No?
Anton	We're gonna crash! [Looks at the teacher with a happy face]
Jannica	Then you have to drive at the same time, or?
Anton	Yes
Jannica	How will you succeed in that?
Linus	I know what you should do Anton! You drive to there, then I drive two more steps and into you.

An important aspect of the teachers' roles in the didactic games going on between them and the children is their ability to connect to the affordances the children experience in the situation. When Anton and Linus tell Jannica about their intention to crash their robots into each other, she encourages their idea with the productive question "How will you succeed in that?". She continues the activity by helping them in their common endeavor by showing them the pause-button and how they can use it to reach the same position at the same time and asks questions about how they should continue. Through this, she challenges the children in their inquiry and learning and helps them to move forward in their intentions with their inquiry. Jannica recognizes the children's own affordances in the situation and builds on them in the didactic game.

Another example of how Jannica promotes a joint inquiry among the children is seen in the next excerpt. In the second step of the inquiry activity where the children freely create obstacle courses for the robots, Mimmi tries patiently, and on her own, to build a bridge in the shape of a V, turned upside down, with KAPLA®-planks. (Figure 4)

Figure 4. Mimmi builds a bridge of KAPLA®-planks for the Blue-Bot®.

The bridge collapses repeatedly when she puts her Blue-Bot® on it and eventually, she gives up. In the example below, she has put the KAPLA®-planks flat on the floor instead, like a mat for the Blue-Bot® to go on:

	[Mimmi seeks the teacher's attention by pulling her arm but since the teacher is in the middle of a conversation with Stella, the teacher ignores Mimmi. Mimmi instead programs the robot and starts it. She puts her hands over her mouth in excitement and anticipation when the Blue-Bot® starts going over her kapla-planks. The teacher now turns her attention to Mimmi's Blue-Bot® and watches it as it goes. Suddenly it stops for a short while, and then continues forward.]
Jannica	[Smiling] Was that a pause?
Mimmi	[Smiles and nods. She has programmed a pause after paying attention to the teacher talking to Anton and Linus about how to use the pause-button, previously. The robot continues forward and stops with its usual beep-sound when it has finished. Mimmi fondly claps her hands and looks at the teacher.]
Jannica	What happened to the bridge?
Mimmi	[Inaudible]
Jannica	What did you say?
Mimmi	It just broke there. [Shows with her finger over the kapla-planks and adjusts the mat she has built from them.]
Jannica	It just broke? How could we have made it so it would hold, then?
Mimmi	[Gets up from the floor and disappears off camera to collect something.]
Jannica	Yes, just get what you need! [Mimmi needed confirmation from the teacher to get the material she intended.]
Jannica	Does anyone have an idea how to help Mimmi build a bridge that holds when a Blue-Bot® goes on it? [Mimmi comes back with a box of blocks in different colours.]
Anton	Yes! You can build a bridge with this! [Leaves his own inquiry on the mat and takes a block from the box Mimmi collected.]

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Stella	I know! One can build… [Runs off to collect a plywood sheet that she comes back with.]
Jannica	Mimmi, look what Stella found!
Mimmi	That one's mine. [Takes her Blue-Bot® from the floor.]
Anton	[Anton aids in building a bridge by putting two kapla-planks on their ends on Mimmi's line of kapla-planks. He then returns to his own inquiry with Linus.]
Stella	You can do like this! Mimmi, you could do like this! [Stella has put the plywood sheet as an inclined plane against the box with kapla-planks. She gets no attention from Mimmi since Mimmi looks at Anton, but puts her own Blue-Bot® on the bottom of the inclined plane, facing upwards.]
Jannica	Look Mimmi, what Stella created, it's a bridge! [Points to the plywood sheet that Stella leaned against the box.]
Mimmi	[Takes her Blue-Bot® and walks over to Stella's bridge and places the Blue-Bot® next to Stella's on the inclined plane.]
Mimmi	Stella, should we have a competition, go up first?
Stella	No!
Mimmi	Try that?
Stella	No, I know! It should come DOWN first! That's what … [Puts her Blue-Bot® at the top of the plane, facing downwards. Mimmi follows her example with her Blue-Bot®.]
Jannica	Oh! Look! [Mimmi and Stella start to program their robots.]

In the excerpt we see how the teacher draws the children's attention towards Mimmi's activity, thereby creating means for joint attention and joint affordances in the situation. Anton and Stella both fall into Mimmi's intention to build a bridge and try to help her with it. Anton goes back to his and Linus' inquiry on the mat but Stella and Mimmi create a joint game and a competition, initiated by Stella's construction of an inclined plane. The creation of the competition may be viewed as a joint attention between the girls. However, this initial joint attention includes no joint affordance experienced by the girls in the situation, since Mimmi intends for the robots to go up the plane while Stella intends for them to go down. They agree on Stella's suggestion to go downwards and through this agreement, a joint affordance in the situation is established. Jannica follows their intentions and continues the didactic game by directing their attention towards a fair trial when the robots compete on the inclined plane:

	[The girls start to program their robots and Stella starts her first.]
Stella	[To Mimmi] Start.
	[Stella presses the start button on Mimmi's Blue-Bot® but it does not start. Stella's robot goes down the inclined plane and finish before Mimmi's robot even starts.]
Stella	I will win, I won. But we start over!
Jannica	Perhaps you should start at the same time.
Mimmi	I haven't started!
Jannica	Yours doesn't run? What's happening to yours?
	[The girls are programming again and the robots go fairly even downwards on the plane.]
Stella	[To her robot] Come on! Both came down on the same time! [Looks at the teacher with a happy face]
Jannica	Did you start them at the same time?

Stella notices the unfair trial when Mimmi's robot does not start, as she states that they must start over. The teacher underlines this by directing Stella's and Mimmi's attention to this important aspect of the didactic game, with the question "Did you start them at the same time?". Jannica's approach to direct the different children's attention to each other's inquiry creates a joint attention in

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the group and opens up for joint affordances.

When all the children in Caroline's activity have walked the arrow path, Caroline expands the didactic game and milieu by opening up for the children's own ideas in the activity:

Caroline	Now we have been robots. Is there anything else you could do with the path?
Alice	I know! You could make an obstacle course.
Caroline	An obstacle course. In what way could you make an obstacle course?
Alice	You can do like this, then you can go here … [Starts to re-locate the papers and arrows in the path a bit to the left and right so that a larger space is created between them. The children will need to jump or take larger steps to get to the next paper/arrow.]
Alice	Then you continue like that! So you have to walk like this, then like this, then … [Shows with her feet on the new path.]
Caroline	You re-build the path?
Alice	Mm
Caroline	Mm
Elias	You could also do like this that you can point to a paper … [Turns an arrow so that it points to a paper.]
Elias	… then the paper points to this paper. [Continues to build the path by turning the arrows in new directions]
Caroline	[Looks at the other children] Yes, 'cause a path could be placed a little here and there.
Children	[Nodding]

Caroline makes use of the children's agency and own ideas in this part of the didactic game. She encourages them to explain their thoughts and opens up for joint attention and joint affordance by confirming one child's idea to all children.

In summary, the analyzed STEM-activities points to several crucial aspects of how the teachers enable and promote the didactic game in their respective situations. First, the teachers and the children recapitulate the group's already established knowledge, that is, the didactic contract, around the Blue-Bots® and the stones and about what a robot could be. Thereafter, the teachers construct a didactic milieu of first teacher-led and then open free, but coached, inquiry, where the children's own thoughts and interests are important parts of the didactic game. By creating interest and teaching the children hands-on, as well as by expanding the learning milieu for both individual children and children working together, the learning game enables joint attention, joint affordances and common ground, i.e. joint action, to be created in the groups.

Discussion

During the implementation phase of the botSTEM project where teachers are trying out, evaluating and modifying the botSTEM activities, we have mostly experienced teachers choosing to start with unplugged versions of the activities, where the children 'program' each other. However, the results of the present study indicate the robots to be strong motivators in enabling joint actions among the children. Interestingly, the two teachers in this study make use of the same didactic strategies in their learning games, despite one including physical robots and the other not, in their teaching about programming. The employed strategies described above, and used for enabling joint attention and joint affordances in the situations, seem to work in both unplugged and digital (plugged) circumstances. Across the varying contracts and milieus in this study we experience the categorized strategies in both cases. It is therefore not clear that a generic recommendation would be to start with unplugged programming – it appears to work both ways. It will depend on the didactical contract and milieu set up by the teacher.

The children's investigations and inquiry taking place in this study can also be said to belong to what Eshach (2006) describes as 'domain-general knowledge' of science, aiming at the scientific

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work processes such as observations, experimentation, discussions, etc. The teacher's strategies for enabling joint action among the children can therefore be described as promoting learning of domain-general scientific knowledge, as well as promoting the didactic game. The coaching approaches seen in the analyzed activities of this study, where the teachers in different ways support the children in their thoughts and observations without providing them exact solutions, may also be seen as examples of what Eshach and Fried (2005) mean when they point to the role of a teacher as one that demonstrates how a comb will deflect a stream of water after the comb has been run through one's hair, rather than speaking of electricity. This kind of reticent coaching strategy has also been discussed as fruitful by Undheim and Jernes (2020) in their case study of technology-mediated story creation with two small groups of young children. The approach is similar to what Fleer et al. (2014) have called having a 'sciencing' attitude and it is a strategy we have discussed previously based on an interview with a preschool teacher after the implementation of a teaching sequence involving water phase changes and digital movie-making (Fridberg et al. 2018a). In the didactic game taking place, the teacher and the children move from the didactic contract involving their previous habits and knowledge of how to program the Blue-Bots® on the floor, to include e.g. programming them up and down inclined planes and cooperating around how two Blue-Bots® can be programmed to 'crash' into each other. The activity thus combines programming and scientific inquiry, or in other words robotics and domain-general scientific knowledge, and provides novel knowledge of how teachers may support learning of the S and T in STEM, in the preschool environment.

The competent child is a perspective that underlies the work presented here and the result indicates that in enabling the children with a power of acting, the learning game proceeds enabling the didactic milieu to develop. This is particularly noteworthy for the given examples of joint action among the participants in the didactic game, where the programming skills and important concept are experienced and instituted in several concrete situations with the Blue-Bots®, as also discussed by Sensevy et al, (2015). The role of the teacher in the didactic games is essential, and several examples are given here of the teachers' persistently maintaining a focus towards enabling development of the didactic milieu, based on the didactic contract and enabling joint actions both between the children and between children and teacher. An example of this is when the teacher Jannica coaches Mimmi to metareflect and express how she thought and visualized the counting of robot 'steps' into the farmhouse. However, note that the teachers here were aided in this by the children's interest in working with experimenting and robots, a comparable result to what was earlier found for experiments scaffolded by a computer tablet (Fridberg et al. 2018b). The pattern of interaction also exemplifies the importance of a teacher that listens to children's perspectives but at the same time challenges the children further by directing their attention towards what the teacher aims for them to learn about. This establishes a relationship between the children's thoughts and expressions and the intended learning in the activity (Fridberg et al. 2019).

A limitation of the study is that it only focuses two teachers and their respective child groups whereby more general conclusions are not possible. However, they are not exceptional cases and we consider the findings to be of interest when discussing teaching approaches for STEM education in early years education. Especially, for teaching, with what we describe as involving a didactic game with set, but dynamic learning goals.

Conclusions

The findings in this study point to fruitful didactic strategies for teachers to make use of when teaching STEM in preschool. The analyzed examples of teacher-led but child-centered approaches described have been found to enable and sustain joint attentions and joint affordances in both groups of children, and show promise for teaching STEM and programming, with and without digital tools. This makes the present study a good basis for discussions about what should constitute STEM education in preschool and the teacher's role in the same. There is a need for future studies of teaching involving programming and robotics including more specific intended objects of learning in the STEM-fields, i.e. using robots to learn about gravitation and friction. Implementations of newly

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developed botSTEM activities for early years with specified learning objectives for both robotics and different STEM contents will be analyzed during 2019. The analysis will have a specific focus on how learning of the involved STEM content can be scaffolded by robotics.

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